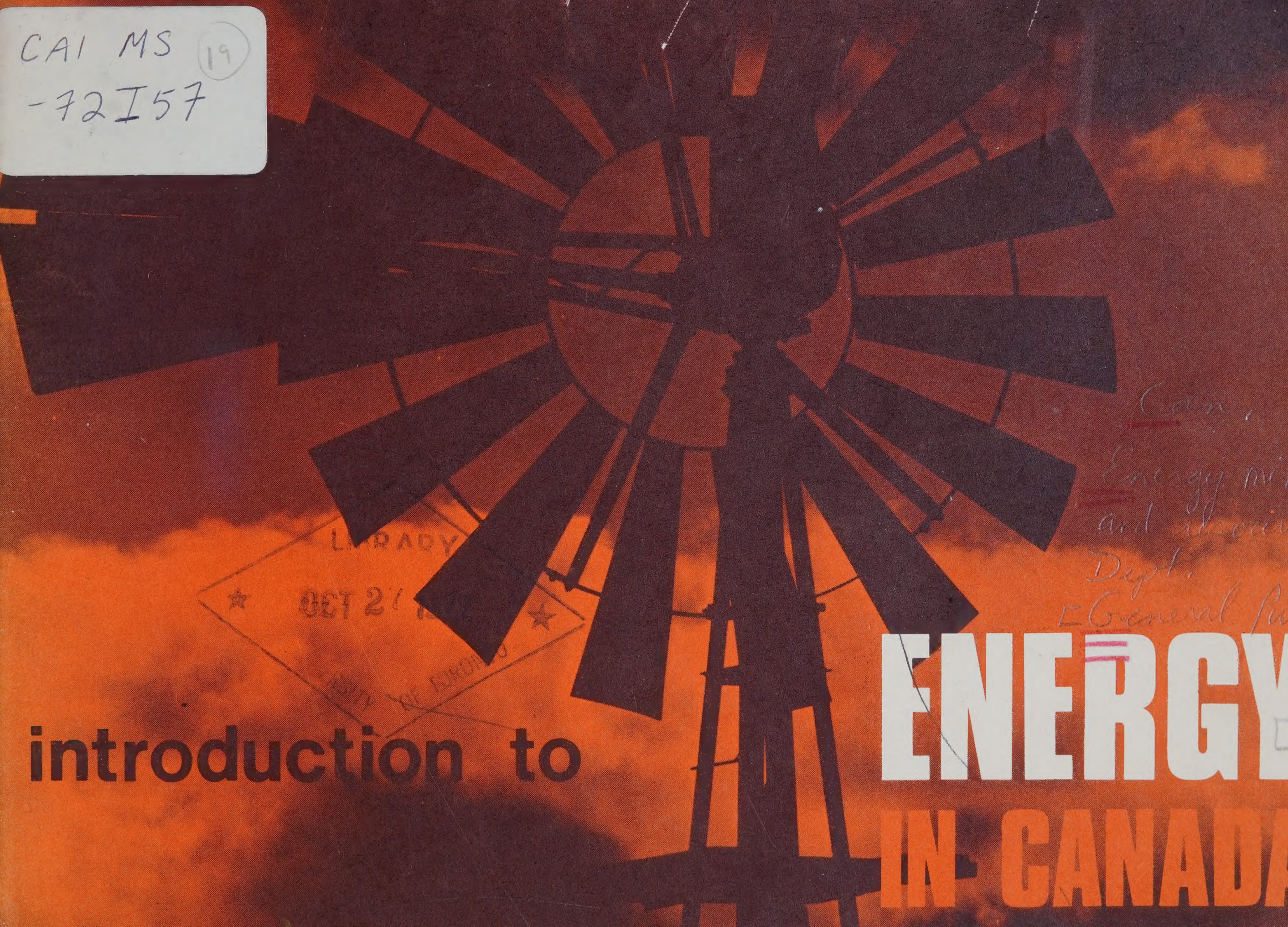

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introduction to ENERGY IN CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA.
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J. AUSTIN, DEPUTY MINISTER

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J. AUSTIN, SOUS-MINISTRE

This wind-driven generator used on a Canadian farm symbolizes a transition from old to new energy forms. Windmills, except in isolated areas, have been replaced by power lines carrying electricity; electrical energy is derived from one of the other energy sources — falling water, fossil fuels or uranium.

introduction to ENERGY IN CANADA

Many anthropologists hold that the most significant step in human evolution was the inception of the use of tools. Other scientists might disagree as many believe the most significant step was the inception of the use of energy other than that of man's own body. The use of "external" energy vastly increased man's control over his environment. Also, each discovery of a new source or application of energy brought about revolutionary changes in the social economy. The history of energy use is a fascinating and enlightening subject that opens our eyes to many things we normally take for granted.

Nearly all energy available on earth ultimately derives from solar radiation. This radiation makes plants grow and thus provides food and fuel for men and animals. (Carbohydrates in food itself is a form of fuel which is "burned" in the body.) The radiation makes water vapor rise which causes rain and snow to fall and rivers to run. It gives rise to variations in atmospheric pressure and thus to winds. The ocean tides — which are a potential source of energy — are caused by the attraction of moon and sun rather than by radiation, but without heat the oceans would be frozen solid. The amount of radiation received by the earth from the sun is staggering. On the average, each 1½ square miles of the earth's surface each day receives the heat equivalent of a Hiroshima-type atomic bomb. Only the nuclear energy stored in uranium and thorium is not derived from solar radiation.

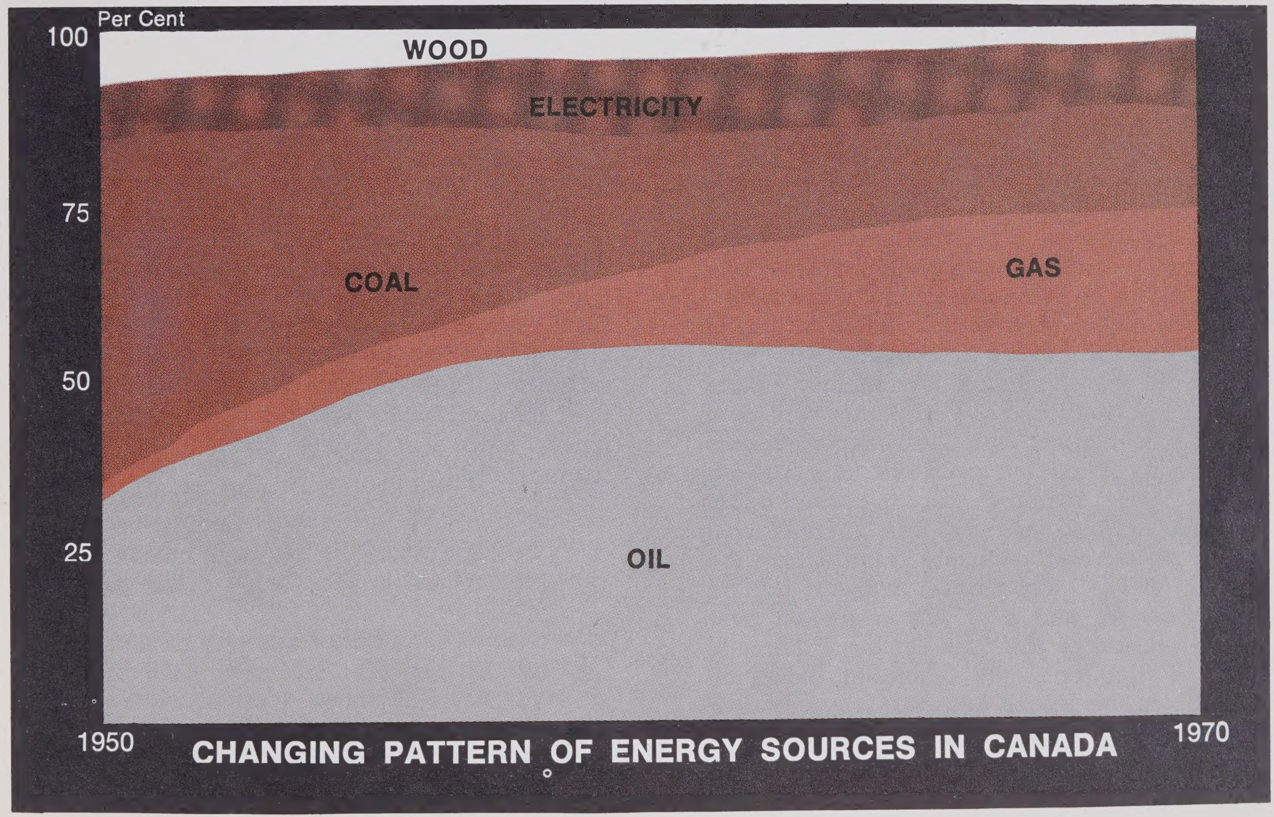
ORIGINAL ENERGY SOURCES

Man is starting to use solar heat directly but from earliest prehistory he has used the "heat" stored in plants and animals. Burning wood is probably the earliest type of energy acquired by man from nature. By burning wood man learned to make his food more digestible, to heat his cave and thus be able to survive in more frigid climates, to light his way at night, to frighten off predators, and to make clearings in the forest. The second important source of energy was the domestication of animals, used chiefly for pulling or carrying loads. Yet another source of energy is the wind, which was used to turn windmills and, more importantly, propel ships. A fourth source of energy is running water which was used to turn waterwheels and to speed the passage of ships and rafts downstream.

These four sources of energy remained dominant well into the 18th and 19th centuries. Coal, and from this was derived steam, then began to supplant wood, animals and wind, at least as far as the industrialized western world is concerned. Coal itself has now been relegated to third place in Canada through the advent of oil and gas, this occurring within less than two decades.

How and why did these startling transformations take place, and what is our nation's present energy situation?

To get answers to these questions, we must take a closer look at the main sources of modern energy — water, coal, oil, natural gas, and uranium. Although wood is still being used as a heating fuel in about one per cent of Canadian households, it is practically extinct as an industrial fuel. Windmills still play a modest part on some farms, but this source of energy is not very important when measured against the nation's total energy consumption, and the same applies to horses and oxen.



CHANGING PATTERN OF ENERGY SOURCES IN CANADA

WATER

Although the waterwheel has been known since antiquity, it did not attain major economic importance until the 20th century. The reason for this may be summed up in a single word: immobility. Nearly all mechanical tasks carried out by man — construction of buildings, roads and bridges, transportation of men and goods, tilling of fields, launching of rockets — require a highly mobile and versatile form of energy. The technology for converting the rotation of the wheel into the complicated operations of the smith and the carpenter was slow in being developed. Thus the waterwheel was used mainly for milling grain and, later, sawing lumber. These, of course, were important tasks, and the right to use suitable streams was highly prized and jealously guarded by the owners. Water mills played a useful part in early Canada, and a private argument over the possession of the falls of the Willamette River, a tributary of the Columbia, did much to embitter the British-American dispute over the possession of the Pacific Northwest.

The waterwheel — or its modern version, the turbine — came into its own only with the advent of the electrical generator. Here, for the first time, was a means of channelling the energy of the wheel into an unimaginable variety of mechanical, chemical, heating and lighting applications and to transmit this energy over great distances. For the first time, also, many waterfalls in Canada which had been looked upon as a nuisance to shipping and, at best, tourist attractions, turned out to be great economic assets. Henceforward, when men spoke of water power, they meant electric power. More will be said about electricity in a later chapter.

COAL

Coal is the fuel that powered the Industrial Revolution in the 18th and 19th centuries and kept industry's wheels turning for a century and a half. Coal was used not only as a fuel to raise steam in factories, locomotives and steamships, but also, in the form of coke, as an essential ingredient in the production of iron and steel. It is notable that, in most industrialized nations, large centres of population developed in close proximity to the coal and iron-ore deposits. In Canada, industrialized areas came into being in the St. Lawrence Valley and, in what became, southern Ontario where there was ready access to large coal and iron deposits in the United States. A coal-steel industrial complex was also built-up on Cape Breton because of local coal deposits and proximity of Newfoundland's iron ore mines.

Coal, in essence, is carbonized vegetable matter. It is therefore not a true mineral, although in common usage it is classified as such. Existing coal deposits are the remains of plants that grew some 250 million years ago. As they accumulated and were covered, these plants first turned into peat and later, under the pressure of gradually accumulating sediments, into coal. The greater the pressure and the longer it lasted, the higher the "rank" of the coal. The highest-ranking and cleanest-burning coal is called anthracite; the lowest, with a low heat value, is lignite. In between are numerous types of bituminous and sub-bituminous coal.

Coal has been known since about 1000 B.C. when it was used by the Chinese, but it was not until the 15th century that it started to come into its own. Firewood and charcoal were fairly abundant in medieval Europe and supplied most fuel needs. The use of coal was actually prohibited in England during the 13th century because of its noxious fumes. The introduction of large iron smelters and, later, the steam engine changed all that. By the middle of the 19th century, the "black gold" was king.

COAL MINING

On the prairies coal for the thermal electric plant in the background is mined in an open-pit (strip mining). Manalta Coal Ltd. photo.

Like most other minerals coal is mined by two basic methods — underground or open-pit; the latter is commonly referred to as "strip mining". Undergound mines have shafts that may be vertical, oblique, or horizontal, depending on the location below ground of the coal deposits. Tunnels branch out from the shafts — these may extend for miles — and the coal is brought out by bucket, conveyor belt, or railway. Underground mining and haulage are carried out with various highly developed types of machinery. Strip mining, which is done with power shovels, consists of removing the overburden of soil and rock directly from the surface so that the coal is laid bare. This method predominates in all coal-producing provinces except Nova Scotia where coal deposits favor deep-mined operations.

The choice of mining method is based on the inclination, thickness and depth below the surface of the coal seams. These seams vary in inclination from the horizontal to the vertical. The most steeply pitching seams occur in mountainous regions whereas the coal under the prairies is flat or nearly so. Seams vary in thickness from inches to fifty feet or more. The depth of the coal under the surface also varies and ranges from ground level to thousands of feet below; currently in Canada, the deepest workings are at 2,500 feet.

CHECKERED HISTORY

In Canada, coal was mined as early as 1720 in the vicinity of the French fortress of Louisbourg on Cape Breton Island. In 1867 at the time of Confederation, annual coal production in Canada was about 631,000 tons. It increased steadily until the end of World War I when it attained 15 million tons. After this, fluctuations set in. Production decreased during the depression but World War II and postwar industrial expansion caused an increase reaching a high of 19.1 million tons in 1950. This declined again to about 11 million tons but since the late 1960's the world-wide demand for coal for use in the production of electrical energy and in the metallurgical industries has led to a dramatic increase in Canada's coal output. This had reached 19.3 million tons in 1971 and experts calculate that, if current economic trends continue, annual production may well surpass 30 million tons in 1975.

Canada has no significant deposits of anthracite, but it has large deposits of bituminous, sub-bituminous and lignite coal, the latter two types being found especially in Alberta, Saskatchewan, and, to a lesser extent, Ontario. Although the Cape Breton deposits represent only a tiny proportion of Canadian coal reserves, they were originally the largest source of coal consumed in this country. Alberta is now the largest producer of coal in Canada, followed by Saskatchewan (lignite), British Columbia, Nova Scotia, and, at some distance, New Brunswick. As far as the total resource is concerned 97 per cent occurs in the three western provinces of Saskatchewan, Alberta, and British Columbia distributed 10, 39 and 48 per cent respectively. The remaining 3 per cent is found principally in Nova Scotia.

Consumption of coal in Canada has always exceeded production by a wide margin. The difference has been made up by imports, mainly from the United States of both thermal and metallurgical grades of coal. Since coal deposits in Canada are abundant, and since actual production in recent years has been rapidly increasing, the reasons why Canada has to import such a vast quantity of coal must, at first glance, seem puzzling.

The explanation is quite simple, and has already been alluded to — the great distance of Canada's major coal deposits from the St. Lawrence Lowlands, Canada's chief manufacturing area. The distance from the Pennsylvania coalfields to Toronto is about 280 miles, from Cape Breton 1,350 miles, and from the Alberta coal deposits, 2,100 miles. These distances have made it uneconomical for Canadian coal to compete against the United States coal by the present methods of transportation.

To make Canadian coal more competitive in Ontario and Quebec the federal government did pay subventions, usually in the form of transportation subsidies, to the mining industry, principally in Nova Scotia. The cost of these payments increased rapidly so that, by the late 1960's, it was not economically sound to continue with the subventions. The Cape Breton Development Corporation (DEVCO), a Crown corporation, was established in 1967 with responsibility to modernize the better coal mines, gradually close the poorer ones and foster new types of industry to provide self-sustaining employment for the unemployed miners who had worked in the mines that closed.

To aggravate the difficult economic position of the coal industry a new and even more serious competitor than United States coal had appeared on the scene in the later 1940's. This was petroleum.

In 1946, the Carroll Royal Commission on Coal found that about one quarter of the coal consumed in Canada was used by Canadian industry, mainly for heating and steam-raising. Another quarter was used for domestic heating. A third quarter was consumed in railway locomotives, which at that time were nearly all steam-powered. The remainder went for central heating systems, the production of coke and artificial gas, synthetic chemicals, and other by-products. Although the Commission acknowledged the economic difficulties of Canadian coal, it was optimistic concerning its status as an energy source: "Despite the importance of alternative sources of energy, coal is, and will probably continue to be, the

most important source of energy for railway locomotives and for industrial and domestic heating."

Rarely has an economic prediction been so wrong. In 1948 Canadian railways consumed over 12 million tons of coal; in 1960, not a single locomotive on the two transcontinental systems used coal. In 1946, most Canadian homes were heated by coal; by 1970 only 1.7 per cent used coal while 90.3 per cent used oil or gas.

CURRENT USES

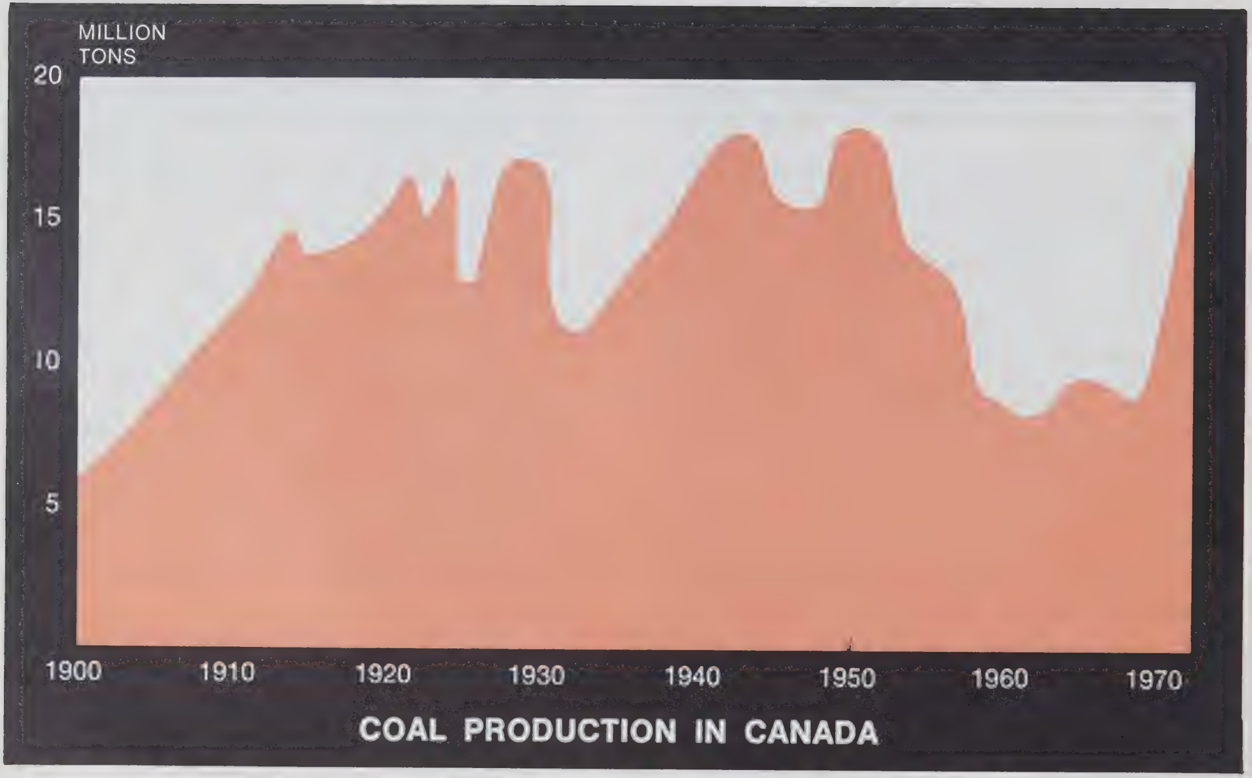
Nevertheless, coal is widely used in two fields — electric power generation and production of iron and steel. In 1970, for example, 15 million tons were used to generate electricity while 8 million tons of bituminous coal were carbonized to produce coke.

Coal must be converted into coke to be used in a blast furnace for the reduction of iron ore. The conversion is done by heating the coal to drive out the volatile components. (These by-products have important chemical uses.) Most of the coke consumed in Canada is produced by the steel industry for its own use.

BRIGHTENING OUTLOOK

The late 1960's saw a considerable improvement in sales by Canadian and world coal industries. The heavy demand of the Japanese steel industry for coking coal has given a tremendous boost to western Canada coal producers. Based on contracts signed by the end of 1970 exports to Japan reached 7.5 million long tons in 1971, and will reach 9.5 million tons in 1972 and surpass 17 million tons per year by 1975.

Expansion of these contracts, or the signing of additional contracts by new companies, is likely as the growth rate of the Japanese steel industry indicates that a gross of 30 million tons of Canadian coking coal may be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COAL PRODUCTION IN CANADA

needed in 1980 in Japan. At that time Canada will likely rank a fairly close third after the United States and Australia as a supplier of coking coal to Japan.

Coal and coke shortages have been reported by most European countries where, for economic reasons, wholesale mine closures occurred during the 1960's. To make up for these closures Europeans have imported increasing quantities of U.S. coals; some of the Canadian producers are now evaluating the prospects of sales to this area as well as to the west coast of both South America and the United States.

The increased domestic market demand for United States coal, from both the power and steel industries, has resulted in some shortages in the early 1970's because of the productive capacity of the U.S. mines unable to cope with the orders. This is gradually improving with new mines being opened but, since it is a seller's market, the mine operators will demand and receive more money for their coal. This increase, plus more costly transportation, will mean higher prices for Canadian users.

Consequently, Ontario coke producers have examined the feasibility of using coal from western Canada. There is a possibility that western Canada coal may, in the future, supplement imports, particularly for producing coke.

It has been calculated that, on a world-wide basis, there is enough coal to last for several hundred years. This is a far greater reserve than that of any other hydrocarbon fuel. The coal resources of western Canada are estimated to be 118 billion tons. Even assuming only 10 per cent are economically recoverable and of suitable quality, this reserve would last 600 years at the present rate of consumption.

PETROLEUM AND NATURAL GAS

If coal was the fuel of the Industrial Revolution in the 18th and 19th century, petroleum is the fuel of the affluent society of the second half of the 20th century.

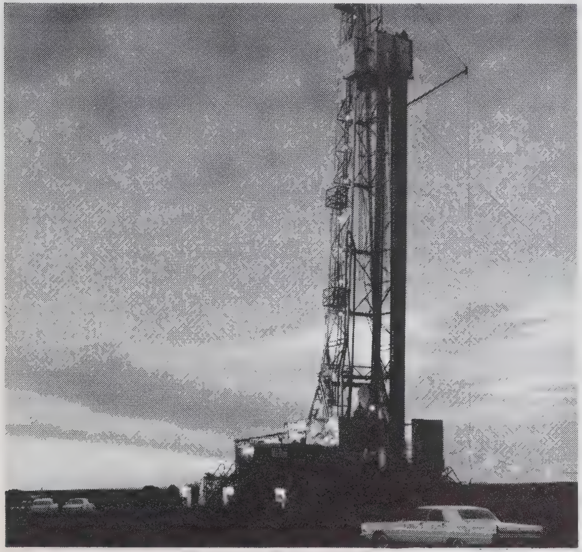
Petroleum, like coal, is a fossil fuel. Its origin, however, is not as clear as that of coal but appears to lie in the decomposition and transformation of vast quantities of tiny marine organisms that populated ancient seas. At any rate, petroleum deposits are never found apart from marine sediments. These sediments, in turn, may be found on what is now land, as in Alberta and Saskatchewan, or under the sea, as in Venezuela's Gulf of Maracaibo, the Persian Gulf and offshore from Canada's east coast. Natural gas may be in solution in oil, in a separate layer above it, or found without oil.

Oil and gas occur in porous rock, overlain by strata of more impermeable rock. The oil is often under pressure from gas or water or both, which may be sufficient to drive it up a well to the surface. The maintenance and, if necessary, replenishment of this pressure by re-injection of gas or water is one of the most important skills in oil-reservoir engineering. Where pressure is insufficient the oil has to be pumped to the surface.

The search for petroleum goes on year after year. The Geological Survey of Canada and provincial surveys carry out broad geological investigations, which form the basis of a more detailed and intensive search by private oil companies. Geophysical techniques — the measurement of seismic, geomagnetic, and gravimetric variations in the earth's crust — have taken much of the old hit-or-miss out of oil exploration. Definite proof, however, must still be obtained by drilling, and millions of feet of wells are drilled annually.

Unlike coal, crude oil is not readily useable in its natural or crude state although it may be used directly in steam boilers of large thermal plants. Crude oil needs to be separated by refining processes into several classes of liquids. The lightest, and most combustible, are the various "light ends" and gasolines; the heaviest are tars and asphalts. In between are kerosene, diesel fuel, heating oils, lubricants,

and various other products. Crude oil may be refined by several methods, such as distillation and catalytic cracking (the break-up and reconstitution of the hydrocarbon molecules).



Modern oil drilling rig. Photo by George Hunter.

Some of the products of refining can, in turn, be used as a basis for chemical products. Sulphur removed during the processing of "sour" natural gas from some fields is also an important chemical base, particularly for the production of sulphuric acid.

Both oil and natural gas have been known since ancient times, but little use was made of them. As in the case of coal, the use of petroleum and its derivatives had to await the development of a civilization ready to absorb them. In a preliminary way, this occurred with the introduction of the kerosene lamp, and in a decisive way with the introduction of the internal-combustion engine. Today that engine reigns supreme where transportation is concerned. Automobiles, locomotives, ships, and airplanes all use it. In Canada, only one special and relatively minor form of transportation not using petroleum is holding its own, and that is the subways in Toronto and Montreal. The other electrically driven types of public transport — streetcar and trolley bus — are declining.

OIL AND GAS IN CANADA

The history of petroleum production in Canada may be divided into three periods. The first began in the 1850's when oil was discovered in the Oil Springs area of Ontario, southeast of Sarnia. Within a few years, numerous wells had been drilled, and in 1895 production totalled 800,000 barrels. After that the pre-eminence of Ontario declined. The second period began with the Turner Valley development in Alberta, where natural gas was found in 1914 and oil in 1922. The third, and by far the most significant, period took its inception from the famous Leduc discovery, also in Alberta, in 1947. In that year, Canadian petroleum production amounted to some 7.7 million barrels; ten years later it had sky-rocketed to 184.8 million.

In the early 1930's, oil and its associate, natural gas, accounted for about one third of Canada's energy; by the early 1970's this share had increased to over three quarters. As the use of oil and gas increased the use of coal as fuel decreased. However, as has already been pointed out in the preceding chapter, from now on oil and gas will not have such a drastic effect on the production of coal.

In 1970, Canadian oil production stood at almost 550 million barrels per year, with Alberta accounting for almost 75 per cent and Saskatchewan nearly 20 per cent. The remainder came chiefly from British Columbia and Manitoba. The Alberta oil fields are widely dispersed about the central part of the province, the most productive ones being in the vicinity of Edmonton. The Saskatchewan oil fields are in the southeast and southwest corners of the province, and the British Columbia fields are located around Fort St. John, in the northeast part of the province.

Reserves of petroleum in Canada are large. At the end of 1970, "recoverable" reserves of crude oil and natural gas liquids were estimated at 10.5 billion barrels, enough for nearly 20 years at current rates of production. In addition to these reserves there are the vast Athabasca oil sands in northeastern Alberta, which are estimated to hold another 300 billion barrels of potentially recoverable oil.

Production of natural gas has kept pace with that of oil. The gaslights of earlier days were, of course, fed not by natural gas but by a by-product of coking. The Ontario fields, however, were rich in gas, and since the early years of this century the value of the natural gas output in that area has exceeded that of oil. In 1947 Canada produced some 70 billion cubic feet of natural gas; in 1970 the annual output had risen to 2,300 billion cubic feet. Of this, Alberta accounted for over 80 per cent, and British Columbia for most of the remainder, with minor amounts from Saskatchewan and Ontario. Reserves of natural gas stood at 54 trillion cubic feet in 1970, or about 29 years' supply at present levels of consumption.

Reserves of both oil and gas may be expected to increase from year to year owing to continued exploration and a favorable resource potential. Exploration was most active in the more southern areas of the country but in the late 1960's it began to increase in the north, including the Arctic Islands, and also in the east coast offshore. Exploratory wells have been drilled off the east and west coasts, in Hudson Bay, the Northwest Territories and the Yukon and in Canada's Arctic Islands. Particular interest now centres on the Far North and the east coast offshore especially since gas and oil have been located in the Arctic Islands and gas on Sable Island.

Canadian production of petroleum and petroleum products by 1970 was equal to the national demand. Canada, however, for economic reasons still imports almost 50 per cent of its requirements while exporting somewhat more than this amount. This is because there is a clear-cut division of oil markets in Canada resulting from a federal government decision in 1961 to reserve the area west of the Ottawa Valley for Canadian oil. Quebec and the Atlantic provinces use Venezuelan, Middle East and African oil. At the same time, Canada exports a considerable quantity of oil and natural gas to the United States, mainly the west coast and the Great Lakes region, including Chicago and Detroit. This has given Canada a favorable over-all trade balance in petroleum.

The best method of transporting oil and gas is by pipeline. Indeed, for gas it has been the only efficient means, whereas oil may also be carried economically by tanker. Recently large volumes of natural gas in liquefied form have also been transported by ocean tanker.

Pipeline construction has paralleled oil and gas production in Canada, since all fields are located far inland. In 1970 there were 18,600 miles of oil pipelines in operation in Canada and about 60,000 miles of gas pipelines.

The longest operational oil pipelines are those of the Interprovincial Pipeline system reaching from central Alberta to southern Ontario, and the Trans Mountain Pipeline from Edmonton to Vancouver and the State of Washington. The most important gas pipelines are the Trans-Canada Pipeline from Alberta to Quebec, and the Westcoast Transmission Company line from the north-east corner of British Columbia to Vancouver. There are numerous lesser pipelines, many of them gathering systems for groups of fields to the principal transmission systems.

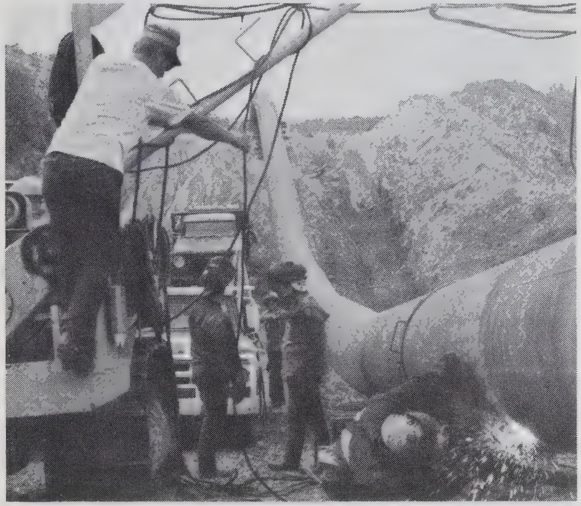
MAIN USES

As a source of energy, liquid petroleum products have three main uses: the internal-combustion and jet engines, heating, and steam-raising (mainly in thermal power plants). Almost 40 per cent of the liquid petroleum products is used for transportation, and close to 60 per cent for heating and steam-raising. The remaining 2 to 3 per cent is used for non-energy purposes such as asphalt, petrochemicals and lubricants.

The advantages of liquid fuels over coal are many. For the same amount of heat, they occupy 50 per cent less space and are 30 per cent lighter. Liquid fuels are more easily transported, they leave almost no ash (the most important requirement for internal-combustion engines), are extremely easy to control, vaporize and ignite, and require little or no attention during combustion.

Natural gas is used mainly for heating. It shares with liquid fuel the advantage of easy combustion, and excels the latter in the cleanness of its flame. It also has disadvantages, however. Owing to its volume it is diffi-

cult to store economically. This is one of the main reasons delaying the use of natural gas in the internal-combustion engine, which normally carries its fuel supply with it. It may



Welders at work on a new section of pipeline on the prairies.

(TransCanada PipeLines Limited photo)

be noted, however, that new liquefaction procedures are opening many future possibilities. Stringent safety precautions are required in the storage and handling of gas, not only because it is subject to explosion, but also because of the danger of asphyxiation in enclosed spaces. The high standard of such safety specifications attained in Canada makes natural gas a widely accepted fuel for cooking and building and water heating. Even in Ontario, whose densely populated area is located 2,000 miles from the chief source of natural gas, the fuel is used so extensively the province accounts for two fifths of Canadian gas sales.

Perhaps the chief disadvantage of oil is that it is a source of air pollution. Research on the petroleum fuels and their combustion is decreasing this undesirable effect but in large metropolitan areas the emission from automobile engines alone is sufficient to cause a serious problem. And, like other non-renewable resources, petroleum some day must eventually be restricted to premium and to non-fuel uses before the supply is exhausted.

URANIUM

The uranium industry grew very rapidly in the early 1940's due to the discovery in 1938 that the isotope of uranium, uranium-235, could be made to fission or split apart with the liberation of both neutrons and a large amount of energy. This, in turn, led to the development of atomic weapons prior to the end of World War II, and was followed by a large weapons stockpile program after the war, not only in the United States, but also in Great Britain, France, the Soviet Union and China. Although it was recognized in those early years that the vast quantities of energy stored in the uranium atom might be developed for peaceful purposes, it is only since the early 1960's that the nuclear power industry has begun to blossom in a substantial way.

Uranium is found in nature usually in low concentrations, characteristically less than ten pounds per ton of ore. In 1945 it was not economic to extract uranium from ores containing less than about 2 per cent uranium, and there were very few of these deposits in the world. Today, however, due to the advances that have been made in extraction techniques, it is possible to economically recover uranium from ores containing as little as 0.1 per cent or about two pounds per ton.

Most of Canada's known economic reserves, which are about one quarter of the free world total, are located in the ancient rocks of the Canadian Shield. The earliest uranium mine was discovered on the shore of Great Bear Lake in 1930, and a small mining camp called Port Radium came into being there as a result. That deposit was developed initially to recover from the uranium ore the traces of radium which were required, in the 1930's, for medical uses. Once the United States atomic bomb project began in the early 1940's, however, the uranium concentrate itself was in great demand.

The military needs during and after World War II gave a tremendous impetus to uranium production, and in 1959 exports of uranium oxide to the United States and Great Britain amounted to nearly 16,000 tons, exceeding in value the export sales from any other mineral.

However, as the military demand slackened in the 1960's, production decreased and many mines were forced to close. In the 1970's the production started to increase again but only to about 5,000 tons per year.

The Port Radium deposit was mined out several years ago and the mine was closed. However, additional large deposits were discovered in the 1950's in Ontario near Elliot Lake and Bancroft, and also in northern Saskatchewan.

The Ontario deposits and the one at Uranium City, Saskatchewan, are mined underground but a large open-pit mine will be in operation in 1975 at Rabbit Lake, Saskatchewan. Once the ore has been mined, the uranium is extracted chemically and converted to uranium oxide for use in nuclear power reactors. Natural uranium contains two isotopes, uranium-235 and uranium-238. The uranium-235 is present to the extent of about one atom in a total of 140. It is the isotope which fissions or breaks up when bombarded by so-called slow or thermal neutrons. These neutrons can cause further fission in adjacent uranium-235 atoms. Hence it is possible to produce what is known as a chain reaction, and to extract the liberated energy as heat. The heat in turn can be utilized for the generation of steam which can then be used to drive a turbo-generator producing electrical power.

The Canadian government participated extensively in financing the early stages of uranium exploration through the Geological Survey of Canada, in mining and refining uranium through the Crown corporation, Eldorado Nuclear Limited, and in carrying out research and development in nuclear energy through the Crown corporation, Atomic Energy of Canada Limited (AECL).

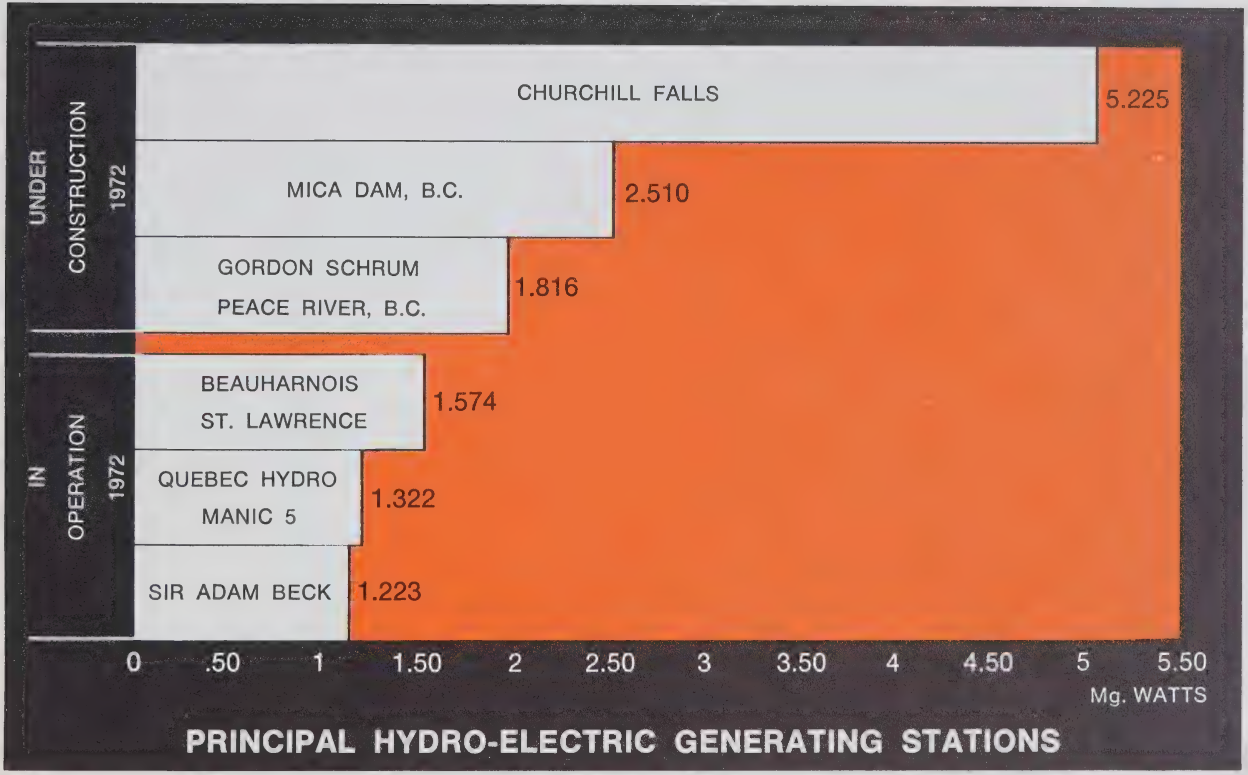
AECL operates a large nuclear research laboratory at Chalk River, Ontario, a smaller one at Whiteshell, Manitoba, a reactor design and development laboratory at Sheridan Park, Ontario, and a facility for the development, production and marketing of radioisotopes in Ottawa.

ELECTRIC POWER DEVELOPMENTS

The dramatic change by the introduction of the electric motor into the factory or the workshop can be appreciated only by someone who has seen an old-fashioned steam-powered plant, with its single engine and long drive-shafts running the length of the building, often repeated on several stories, their numerous pulleys and drive-belts all roaring, whining, and flapping simultaneously. This system was not only cumbersome and wasteful — a steam engine cannot be started or stopped abruptly and the entire machinery had to run idle much of the time — but also dangerous. Equally dramatic is electric lighting when compared with the kerosene lamp or candle.

The 20th century has seen increasing use of water power for hydroelectric generating stations in Canada, the first of which was built at North America's most famous waterfall, Niagara Falls. Other hydroelectric plants built in the early years of the century were located on the Kootenay River in British Columbia, the Winnipeg River, the Ottawa River at Ottawa, and the St. Maurice River in Quebec. These plants have since been joined by many others while new developments are in the construction stage.

Quebec and Ontario are the provinces with the largest installed hydroelectric generating capacity in Canada, followed at some distance by British Columbia and Manitoba. Total hydroelectric capacity in 1970 in Canada amounted to over 28,300,000 kilowatts compared with over 14,300,000 kilowatts in thermal, mostly steam-powered, capacity. Hydroelectric power in Canada thus outweighed thermal power two to one. This is a situation quite different from that in the United States, where thermal power predominates five to one. However the favorable ratio of hydroelectric power in Canada will gradually diminish even though only about one fourth of available water power in Canada has thus far been developed. It must, however, be borne in mind that many promising hydroelectric sites are far from industrial and population centres, and their potential is theoretical rather than practical. By the mid-1980's thermal generating plants,


UNDER CONSTRUCTION 1972
IN OPERATION 1972
CHURCHILL FALLS
5.225
MICA DAM, B.C.
2.510
GORDON SCHRUM PEACE RIVER, B.C.
1.816
BEAUHARNOIS ST. LAWRENCE
1.574
QUEBEC HYDRO MANIC 5
1.322
SIR ADAM BECK
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Mg. WATTS
PRINCIPAL HYDRO-ELECTRIC GENERATING STATIONS

including those powered by nuclear energy, will have overtaken the capacity of the hydroelectric stations.

Hydroelectric stations will continue to be built, nevertheless, in remote areas mainly as a result of improved techniques in designing extra-high voltage transmission systems. Hydro Quebec has developed a 735 kV alternating current system while in Manitoba a high voltage direct current of 900 kV is used on a system from the Nelson River to Winnipeg, a distance of about 550 miles. Economic energy costs for these systems is dependent on the transportation of large blocks of power.

Another possible source of electrical energy is the giant tides of the Bay of Fundy, an arm of the sea between New Brunswick and Nova Scotia. A federal-provincial board, which carried out an extensive engineering and cost study of the potential, reported in 1970 that tidal-power plants would be too expensive to compete economically with thermally generated power. New technology, rising costs of fuel for thermal plants, or new anti-pollution laws may make tidal power feasible or desirable in the future.

Availability of hydroelectric power has also created Canada's ability to produce commercially one quarter of the world's aluminum although no deposits of aluminum ore are found in Canada and the bauxite has to be imported. Aluminum is extracted by an electrochemical reaction requiring an enormous amount of power. Large aluminum plants, such as those located at Alma, Arvida, and Shawinigan in Quebec, and at Kitimat in British Columbia, have all been built by large waterfalls, the source of the needed hydroelectric power.

Manitoba's Kettle generating station under construction on the Nelson River. Manitoba Hydro photo.

HYDROELECTRICITY — PROS AND CONS

In principle, hydroelectric plants have several important advantages over thermal power. They are powered by a perpetually self-renewing energy source, and are therefore economical to operate. The turbines can be started or stopped quickly, and so can respond very rapidly to what is known as "peaking load" i.e., periods of high power consumption. They do not pollute the atmosphere and maintenance costs are low.

There are also disadvantages, however. Although hydroelectric plants are inexpensive to operate, they are expensive to build. In most cases dams, tunnels, canals, and similar major works have to be constructed, often in remote and difficult terrain; also, financial compensation may have to be provided for the loss of land that may be flooded or otherwise impaired. (This, of course, may be outweighed by such benefits as the creation of water reservoirs for irrigation, flood control or recreation.) Hydroelectric installations interfere with the natural river flow, and may affect fish life and other biological regimes. For example, the large hydroelectric potential of the Fraser River in British Columbia has, as yet, not been tapped because of concern for the spawning runs of the valuable Pacific salmon. Hydro developments are often located at considerable distances from major consumers requiring additional cost of transmission.

THERMAL POWER

As we noted in the section on electric power developments the amount of thermally generated power is increasing in Canada. Although thermal plants, if so designed, can switch from coal to oil or gas (or vice versa) 74 per cent of Canada's thermal power was derived from coal in 1970. Alberta, Saskatchewan, Nova Scotia and Prince Edward Island receive most of their electricity from thermal plants compared to 40 per cent for Ontario.

Another type of thermal generating plant, discussed in the next chapter, is the one powered by nuclear energy. This type of plant will become more numerous in the future; it is estimated that by the 21st century nuclear power will provide over 50 per cent of the world's energy needs.

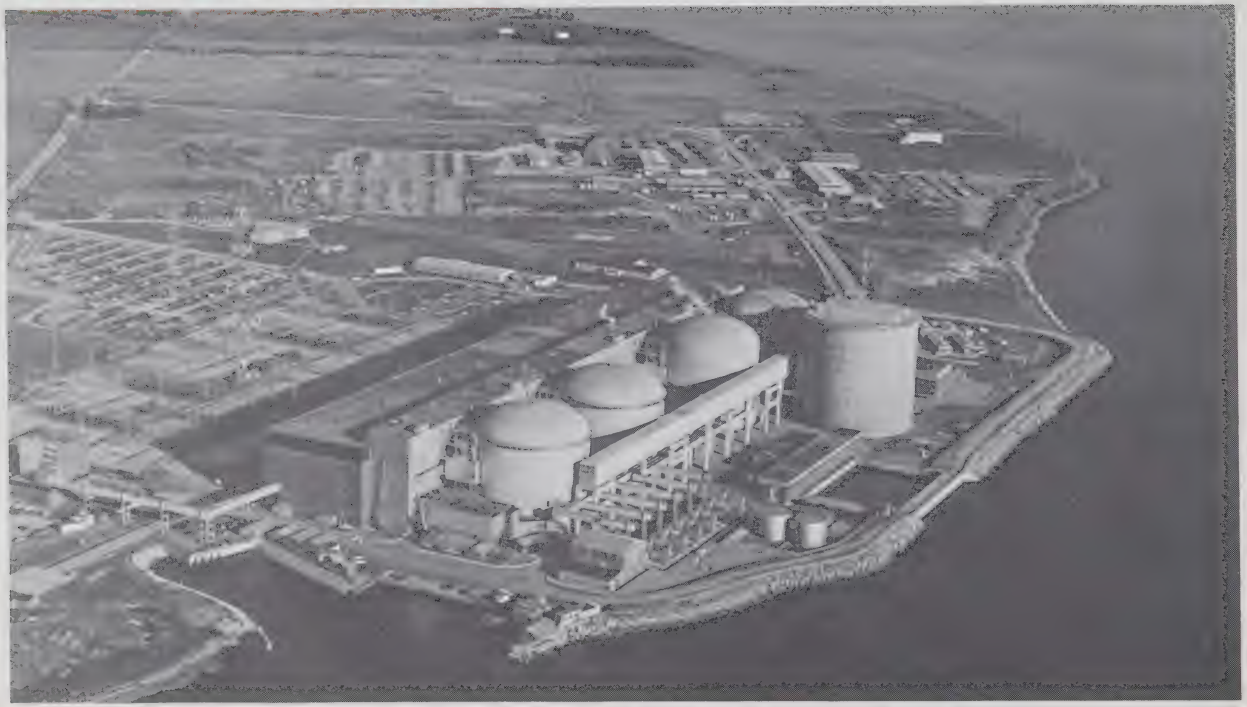
THERMAL POWER — PROS AND CONS

The chief advantage of thermal power stations is that they can normally be located close to the major centres of consumption, thus eliminating the need for costly transmission lines. There are no dams or reservoirs to build, and thermal generating plants are usually considerably cheaper than hydroelectric ones.

There are also disadvantages. Thermal plants are dependent on a fuel with a fluctuating (but generally rising) price. Unlike water power, the fossil fuels are a non-renewable resource, and although reserves, especially coal, seem abundant at present they will not last forever. Thermal plants contaminate the environment in two ways — through the gases and particulate matter including sulphur oxides given off by the burning coal and other fuels and through "thermal pollution". The latter is caused by the warming of large quantities of river or lake water that is pumped through the plant to condense the steam. This may be harmful to fish and other aquatic life. Maintenance costs are relatively high. Power output is not as flexible as in hydroelectric plants. These disadvantages are, however, being reduced through research and engineering. It should also be noted that hydro and thermal power can be used in combination, so that the two types of generation complement each other.

Although the modern steam plant still manages to use only about 35 per cent of the total energy given off by the burning fuel (as against the 90 per cent efficiency of water power) the modern steam turbine is a far cry from the comparatively primitive piston-type machines of the 19th century. Turbines are in general use and the steam driving them may have a pressure exceeding 2,000 pounds per square inch and a temperature of over 1000° Fahrenheit. Gas turbines and diesel engines are also employed as prime movers for electrical generation.

NUCLEAR POWER REACTORS

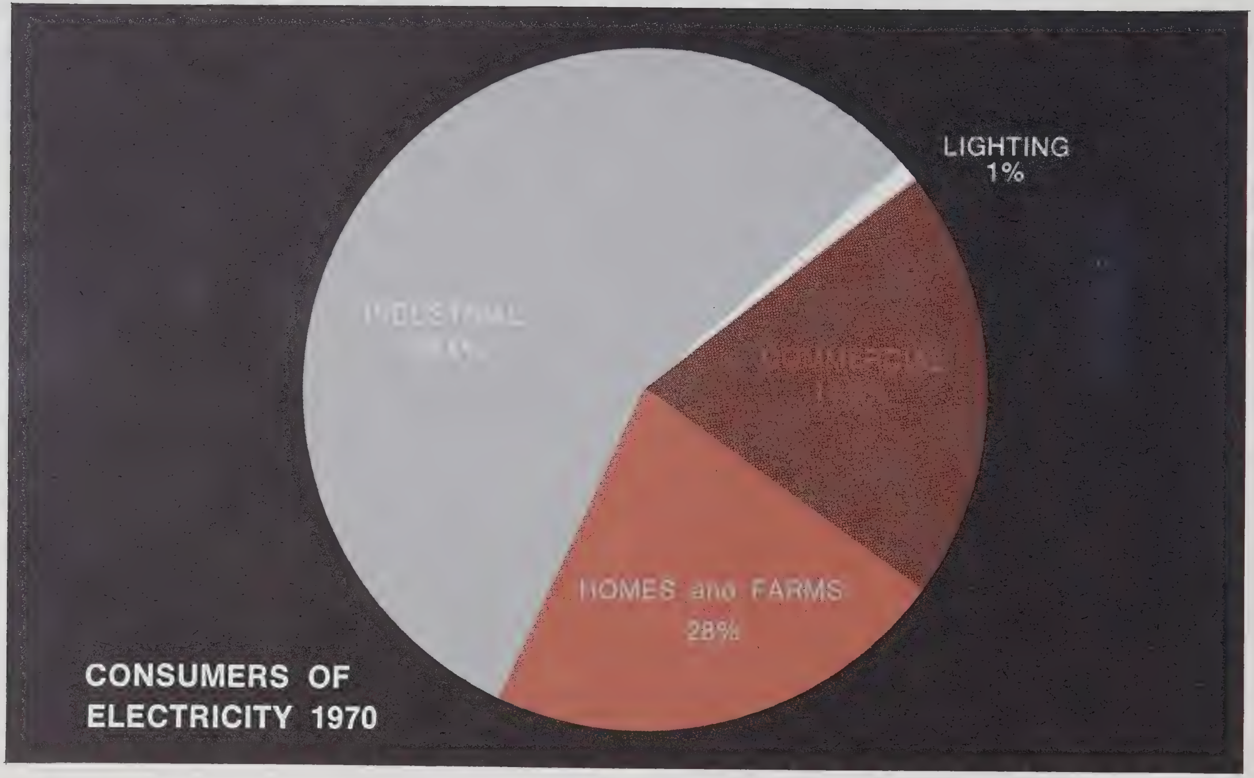


Pickering nuclear power station on the shore of Lake Ontario. Ontario Hydro photo.

The nuclear power industry in the early 1970's is growing at a rapid rate so that 10 per cent of all the electric power produced in Canada will by 1980 come from the fissioning of uranium. The uranium serves as a source of heat in the same sense as does the burning of oil, gas or coal. This heat is converted to steam which is used to drive turbo-generators for the production of electricity. Hence a substantial part of nuclear power stations is similar in design and construction to conventional plants burning coal, for example.

There are many different types of nuclear power reactors in the world, some of which use natural uranium and some enriched uranium. To produce enriched uranium, the natural product must be subjected to a costly and difficult process in which the concentration of the fissionable uranium-235 isotope is increased to perhaps four or five times the level which is present in nature. A typical nuclear power station consists of a fuel, such as uranium oxide, and a moderator such as graphite, light water or heavy water, and a coolant to remove the heat from the reactor. The moderator is used to slow down the energetic neutrons to the velocities where they are captured more efficiently by the uranium-235 atoms. The moderator used in reactors of Canadian design, the CANDU reactors, is heavy water. This is an expensive liquid which is separated from natural water in large chemical plants designed specifically for that purpose. In many of the Canadian reactors the heavy water is not only used as a moderator, but also as a coolant. Other coolants have also been used in power reactors around the world, such as ordinary or light water, carbon dioxide, helium, molten salts, organic liquids and even liquid metals such as sodium.

Towards the end of 1971 Canada reached a position of distinction with its nuclear power program, in that the huge Pickering Generating Station on the shore of Lake Ontario near Toronto began to produce a very substantial amount of electrical power — 1,000,000 kilowatts — from the first two of its four scheduled reactors. In fact, for several months, it was the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largest nuclear power station in operation anywhere in the world. An even larger station of the same design, moderated and cooled by heavy water, is under construction on the shore of Lake Huron near Kincardine. It is called the Bruce Generating Station. In addition, a heavy water moderated reactor of new design, one cooled with boiling light water, is now in operation near Gentilly, Quebec. Other even more advanced designs are on the drawing boards in the engineering offices of Atomic Energy of Canada Limited at Sheridan Park near Toronto.

Nuclear energy developments were financed largely by government because of the wartime and postwar secrecy surrounding nuclear energy and because of the enormous investment in skills and materials that was necessary before nuclear power reactors could become profitable propositions. The stage is rapidly being reached, however, where they are becoming commercial pieces of hardware which are purchased by electrical utilities using conventional financing methods. In Canada, most of the nuclear power developments are occurring in provinces where the electrical utilities are publicly-owned, notably in Ontario and Quebec. It is anticipated that nuclear power developments will be built later in New Brunswick, Manitoba and perhaps British Columbia.

The commercial nuclear power stations now in operation or under construction in Canada were developed and designed by AECL engineers in conjunction with personnel from provincial utilities. The generating stations are operated by utilities staff. Private industry has also begun to participate in the exploitation of nuclear energy through the fabrication of nuclear fuel and the many machines, instruments and components used in a nuclear power station.

Nuclear power has certain clear advantages over coal and oil. First, it does not pollute the atmosphere because the radioactivity produced is carefully contained. Second, nuclear plants may be located almost anywhere without regard to the distance from the fuel source; the amount of uranium fuel needed to

keep a nuclear reactor in operation is so small that transportation costs can almost be disregarded. In other words, so far as the fuel is concerned, it matters little whether a nuclear plant is located next to the uranium refinery at Port Hope, Ontario, or two thousand miles away in western Canada.

DEPARTMENT OF ENERGY, MINES AND RESOURCES

In October, 1966, the former federal Department of Mines and Technical Surveys was reorganized by Act of Parliament into the Department of Energy, Mines and Resources. An important part of the reorganization was the task given to the new department in evaluating and coordinating energy policy.

One of the department's fundamental and continuing projects is to maintain an inventory of Canada's energy sources and a forecast of domestic needs. This inventory takes into account the supply, based on earth science data, and the demand, established from the best forecasting technology and consumer market research.

A number of Crown corporations and agencies, which deal with different aspects of energy and energy policies, have been established. Among these are the National Energy Board, set up in 1959, which regulates the construction and operation of interprovincial and international oil and gas pipelines and matters having to do with the export of natural gas and electric power; Atomic Energy of Canada Limited and the Cape Breton Development Corporation, both referred to in the preceding pages; Atomic Energy Control Board established in 1946; and Uranium Canada, Limited, incorporated in 1971. The latter acts as an agent on behalf of the federal government with respect to the acquisition and future sale of a joint stockpile of uranium concentrates established under an agreement with Denison Mines Limited, located at Elliot Lake, Ontario.

In a federal state such as Canada, natural resources normally fall under provincial jurisdiction, and each province regulates the use of

these resources within its borders. The federal government, however, can do a great deal to encourage resource development through research, by tax and other financial incentives, and by entering into cooperative agreements with one or more of the provinces. An example of one of these agreements is the federal-provincial aeromagnetic surveys, a twelve-year program covering most of Canada. These surveys, scheduled for completion in 1974, have played a vital part in opening up Canada's hinterland to mineral exploration.

Nevertheless, experience has shown that a central agency is needed to provide a long-range view on Canada's energy resource development policy. The department, through its Energy Development Sector, deals with such questions as the reserves of fossil fuels and uranium, water power potential, transportation and transmission systems market allocations, structure of the energy industries, and many other related subjects from which sound policy recommendations can be made. This is necessary, not only for the most effective allocation of the government's financial resources and the determination of national priorities, but also to recognize new opportunities for energy resource development and marketing as well as to provide indications of weaknesses in the energy economy.

A LOOK TO THE FUTURE

To meet the growing needs for energy, not only in Canada but throughout the world, the continuing search for energy sources will increase in the coming years.

— Efforts will be made to find additional reserves of oil, gas and coal as well as the most economical means of recovering these resources from the remote areas of the country. This includes the Arctic Islands and offshore areas.

— Coal production, especially in the western provinces, will continue to increase to meet Canada's internal needs as well as supplying the growing export market. Once an economical way can be found, possibly using a slurry pipeline or unit-trains to transport coal to Ontario and Quebec there may also be an increasing demand for coal from the prairies rather than relying totally on imports from the United States.

— Feasibility of large scale hydroelectric developments in isolated areas will be studied combined with more economical methods of bringing the power to the potential market. The James Bay development in northern Quebec, for example, may be one of the largest power developments in the world.

— The world market for uranium is predicted to rise rapidly in the later 1970's and beyond as more nuclear power stations are put into use. This demand will result in increased production for Canadian uranium mines plus extensive exploration to find additional economically extractable deposits. Research into more advanced types of reactors will progress to ensure more efficient utilization of our uranium resources.

— Research on solar energy will increase to tap this immense source of radiation, which should have an important role in energy use in the 2000's.

Canada will play a vital role in the search for energy in the last three decades of this century but only through a carefully planned development of her resources will there be a beneficial effect on the national economy, the nation's environment and the life style of the Canadian people. The federal government is planning now for this eventuality.